

What is claimed is:

1. A process for enhancing blood vessel images within images of a region under skin of a part of a living body, said process comprising the steps of:

saving unenhanced image data representing the image of the region under the skin  
5 of the part of the living body;

copying said unenhanced image data to create a copy of said unenhanced image data;

transforming said copy of said unenhanced image data to produce transformed image data;

10 smoothing a substantial portion of said transformed image data to produce smoothed image data;

retransforming said smoothed image data;

inverting said retransformed smoothed image data to generate inverted image data, wherein said inverted image data comprises enhanced images of blood vessels; and

15 adding at least a portion of said inverted image data to at least a portion of said saved unenhanced image data to generate a result image in which said enhanced images of blood vessels are shown within the image of the region under skin of the part of the living body.

2. The process of claim 1 wherein said smoothing step comprises the step of  
20 blurring said transformed image data to produce smoothed image data.

3. The process of claim 2 wherein said blurring step comprises Gaussian blurring said transformed image data, wherein said Gaussian blurring step comprises initializing a

kernel and wherein said initializing step comprises the steps of:

generating an effectively-dimensioned kernel array;

padding said effectively-dimensioned kernel array to produce an effectively dimensioned padded kernel array; and

5 transforming said effectively padded kernel array.

4. The process of claim 3 wherein said step of generating an effectively dimensioned kernel comprises the step of generating a kernel having a base radius of approximately 51.

5. The process of claim 4 wherein said step of padding said effectively-  
10 dimensioned kernel array to produce an effectively-dimensioned padded kernel array comprises the step of padding said effectively-dimensioned kernel array to produce a kernel padded to a size with a height having a power of two and a width having a power of two.

6. The process of claim 5 wherein said step of padding said effectively-  
15 dimensioned kernel array to produce an effectively-dimensioned padded kernel array comprises the step of padding said effectively-dimensioned kernel array to produce a kernel padded with a black border to a size of 1024 by 512 pixels.

7. The process of claim 2 wherein said blurring step further comprises the step of frequency-convolving said transformed image data to produce smoothed image data.

20 8. The process of claim 1 further comprising the step of padding said copy of said unenhanced image data to produce padded image data, wherein said transforming step comprises transforming said padded image data to produce transformed image data.

9. The process of claim 1 further comprising the step of contrast stretching said result image to include a substantially full range of pixel values to generate a stretched image.

10. The process of claim 9 further comprising the step of applying an effective gamma curve to said stretched image to generate a gamma corrected image.

11. The process of claim 1 further comprising the step of applying an effective gamma curve to said result image to generate a gamma corrected image.

12. The process of claim 11 further comprising the step of padding said copy of said unenhanced image data to produce padded image data, wherein said transforming step comprises transforming said padded image data to produce transformed image data.

13. The process of claim 1 wherein said unenhanced image data is analog image data and wherein said process further comprises the step of converting said analog unenhanced image data to an effectively-dimensioned digital image array.

14. The process of claim 13 wherein said step of converting said analog unenhanced image data to an effectively-dimensioned digital image array comprises the step of converting said analog image to an 8-bit grayscale image array.

15. The process of claim 1 wherein said smoothing step comprises blurring a substantial portion of said transformed image data and wherein said blurring comprises the step of generating a blur kernel from a standard deviation determined to be effective for enhancing blood vessels.

16. The process of claim 15 wherein said blurring step comprises Gaussian blurring a substantial portion of said transformed image data and wherein said Gaussian

blurring comprises the step of generating a Gaussian blur kernel from a standard deviation in the range of between about 10 pixels and 23 pixels.

17. The process of claim 1 further comprising the steps of repeating said saving, transforming, smoothing, retransforming, inverting, and adding steps at a rate sufficient to  
5 produce a sequence of result images in substantially real time.

18. The process of claim 17 wherein said repeating step comprises repeating said saving, transforming, smoothing, retransforming, inverting, and adding steps at a rate of at least five times per second.

19. The process of claim 1 further comprising the step of selecting a ratio of said  
10 inverted image data to be added to said saved unenhanced image data to generate said result image, wherein said selecting step is performed prior to performing said adding step.

20. A computer program product for enhancing blood vessel images within images of a region under skin of a part of a living body, said computer program product comprising:

15 program means for creating a copy of saved unenhanced image data corresponding to said image of the region under skin of the part of the living body;

a digital transformer for transforming said copy of said saved unenhanced image data to produce transformed image data;

a smoothing operator for smoothing a substantial portion of said transformed image  
20 data to produce smoothed image data;

a retransformer for retransforming said smoothed image data;

a digital inverter for inverting said retransformed smoothed image data to generate

inverted image data, wherein said inverted image data comprises enhanced images of blood vessels; and

an adding function for adding at least a portion of said inverted image data to at least a portion of said unenhanced image data to generate a result image in which said enhanced images of blood vessels are shown within the image of the region under the skin of the part of the living body.

21. The computer program product of claim 20 wherein said smoothing operator comprises blurring means.

22. The computer program product of claim 21 wherein said blurring means comprises 2-D Gaussian-blurring means comprising:

a kernel generator for generating an effectively-dimensioned kernel array;

a kernel padding operator for padding said effectively-dimensioned kernel array to produce an effectively-dimensioned padded kernel array; and

a kernel transforming operator for transforming said effectively padded kernel array.

23. The computer program product of claim 22 wherein said kernel generator generates a kernel having a base radius of approximately 51.

24. The computer program product of claim 22 wherein said effectively-dimensioned padded kernel array is padded to a size with a height having a power of two and a width having a power of two.

25. The computer program product of claim 24 wherein said effectively-dimensioned padded kernel array is padded with a black border to a size of 1024 by 512

pixels.

26. The computer program product of claim 21 wherein said blurring means comprises frequency convolving means.

27. The computer program product of claim 20 further comprising padding means  
5 for padding image data to produce padded image data, and wherein said digital transformer transforms said padded image data to produce transformed image data.

28. The computer program product of claim 20 further comprising a contrast stretcher for stretching said result image to include a substantially full range of pixel values to generate a stretched image.

10 29. The computer program product of claim 28 further comprising gamma correction means for generating a gamma corrected image from said stretched image.

30. The computer program product of claim 20 further comprising gamma correction means for generating a gamma corrected image from said result image

31. The computer program product of claim 20 wherein said smoothing operator  
15 comprises blurring means for blurring a substantial portion of said transformed image data and wherein said blurring means comprises the means for generating a blur kernel from a standard deviation determined to be effective for enhancing blood vessel images

32. The computer program product of claim 31 wherein said blurring means comprises Gaussian blurring means and wherein said means for generating a blur kernel  
20 comprises means for generating a Gaussian blur kernel from a standard deviation in the range of between about 10 pixels and 23 pixels.

33. The computer program product of claim 20 further comprising means for

outputting a sequence of result images in substantially real time.

34. The computer program product of claim 33 wherein said means for outputting a sequence of result images outputs result images at a rate of at least five result images per second.

5        35. The computer program product of claim 33, wherein said adding function further comprises a ratio selector for selecting a ratio of said inverted image data to be added to said saved unenhanced image data in order to generate said result image.

36. An image enhancement and display system for enhancing blood vessel images within images of a region under skin of a part of a living body, said system comprising:

10        a computing unit having a memory and a signal input for accepting a signal corresponding to unenhanced image data and saving said unenhanced image data into said memory ;

          a computer program product stored in said memory and executable by said computing unit, said computer program product comprising:

15                program means for creating a copy of said unenhanced image data stored in memory;

                  a digital transformer for transforming image data to produce transformed image data;

                  a smoothing operator for smoothing a substantial portion of said transformed image data to produce smoothed image data;

                  a retransformer for retransforming said smoothed image data;

                  a digital inverter for inverting said retransformed smoothed image

data to generate inverted image data, said wherein said inverted image data comprises enhanced images of blood vessels;

an adding function for adding at least a portion of said inverted image data to at least a portion of said unenhanced image data to generate result image data in which said enhanced images of blood vessels are shown within the image of the region under the skin of the part of the living body; and

output means for outputting said result image data;

first transmitting means for accepting said result image data from said output means

and transmitting a signal corresponding to said result image data; and

a display device adapted to accept said signal from said transmitting means and to display a result image based upon said accepted signal.

37. The system of claim 36 further comprising a headset comprising said display device.

38. The system of claim 37 wherein said headset further comprises said computing unit and said transmitting means.

39. The system of claim 36 wherein said display device is a computer monitor

40. The system of claim 36 further comprising a detection assembly comprising:

an infrared emitter configured to illuminate the region under the skin of the part of the living body; and

an infrared detector in communication with said signal input of said



computing unit, said infrared detector being adapted to detect infrared emissions reflected from said region under the skin, create unenhanced image data from said detected infrared emissions, generate said signal corresponding to unenhanced image data, and to send said signal to said signal input of said computing unit.

5           41. The system of claim 40 wherein said infrared detector is a CMOS receptor adapted to generate said signal corresponding to unenhanced digital image data.

          42. The system of claim 36 further comprising a second transmitting means for accepting said result image data from said output means and transmitting a second signal corresponding to said result image data.

10           43. The system of claim 36 wherein said computer program product is adapted to be executed sequentially such that said output means outputs a sequence of result images in substantially real time.

          44. The system of claim 46 wherein said output means outputs a sequence of result images at a rate of at least five times per second.

15           45. A system for capturing images of a region under skin of a part of a living body, enhancing blood vessel images within captured images, and displaying enhanced result images in substantially real time, said system comprising:

          an infrared emitter configured to illuminate the region under the skin with waves of infrared light;

20           an infrared detector configured to accept waves of infrared light reflected from the region under the skin, said infrared detector comprising an output for outputting a signal corresponding to unenhanced image data;

a computing unit comprising an input for accepting said unenhanced image data, a memory, means for enhancing and outputting result images in which enhanced images of blood vessels are shown within the images of the region under the skin of the part of the living body, and an output for outputting said enhanced images; and

5        a display device for inputting said enhanced images from output of said computing unit and displaying said enhanced images in substantially real time.

46. The system of claim 45 wherein said means for enhancing and outputting result images outputs said result images at a rate of at least five images per second.

47. The system of claim 45 wherein said infrared emitter comprises two arrays of  
10    surface mounted light emitting diodes comprising integral micro reflectors.

48. The system of claim 47 wherein said infrared detector is a CMOS receptor adapted to generate digital data corresponding to skin-reflected infrared wave reception.

49. The system of claim 45 wherein said infrared detector is a CMOS receptor adapted to generate digital data corresponding to skin-reflected infrared wave reception.

15        50. The system of claim 45 wherein said computer program means comprises:  
a digital transformer means for transforming image data to produce transformed image data;

a smoothing operator for smoothing a substantial portion of said transformed image data to produce smoothed image data;

20        a digital retransforming means for retransforming said smoothed image data

a digital inverter for inverting said smoothed image data to generate inverted image data; and

an adding function for adding said inverted smoothed image data to unenhanced image data to generate a result image.

51. The system of claim 45 further comprising a headset and at least one battery in electrical communication with said computer unit, and wherein said display device, said computing unit, and said at least one battery are attached to said headset.

52. The system of claim 51 wherein said infrared emitter and said infrared detector are attached to said headset.